NRCB

PERSPECTIVE PLAN

VISION 2025

NATIONAL RESEARCH CENTRE FOR BANANA

(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)

Tiruchirappalli-620102, Tamil Nadu.

CONTENTS

FORWORD PREFACE

Banana and plantain constitute 32% of the total fruit production from 12% of the area under fruits. India is the largest producer of banana in the world with a total production of 16.9 million tons from 6.9 lakh hectares. During the last two decades, production and productivity has considerably increased with appreciable area expansion due to the growing awareness of banana in nutrition, high economic returns and its export potential.

The National Research Centre for Banana (NRCB) was established at Tiruchirapalli, Tamil Nadu on 21st August, 1993 to strengthen the basic and strategic research and to improve the production and productivity of banana in India. The Centre has made concerted efforts to collect wild *Musa* and its related species and also cultivated accessions from exotic and indigenous sources. The collections were evaluated and Finger printed by morphologically and molecular means. Standardized various production technologies to improve the land use, fertilizer use and water use efficiency. Also, developed eco-friendly integrated pest and diseases management for the control of corm and stem weevil, nematodes, fungal and post harvest diseases. Molecular diagnostic kit has been developed for the identification major viruses, for the elimination and production of disease free healthy plants. Post-harvest and storage techniques have been developed, for extending the green life and yellow life of fruits of different commercial cultivars and also technology for export of banana. To maximize the profitability, 14 value added byproducts have been developed and 4-5 products have been commercialized.

Due to erosion of wild bananas in their natural habitat, there is a need to conserve the available genetic diversity. Production constraints also vary from region to region; however, many problems are similar in nature. Breeding banana and plantain has its inherent complex problems and recent biotechnology tools/approaches help to achieve the expected results in the near future. With a production target as 25 million tons in the year 2020, the major production constraints like increasing input costs of fertilizers, irrigation and management of insect pests and diseases are to be solved for maximizing the production. Decreasing soil health and substrate dynamics management is a great challenge, to maintain a better eco-system and environment.

In this perspective plan, current status of banana research, constraints, gaps, future thrust areas and approaches have been discussed. New initiatives have been envisaged in the high priority areas like genetic conservations, molecular breeding, substrate dynamics, organic farming, integrated pest and disease management, physiological, bio-chemical and genetic basis for biotic and abiotic stress management, post harvest technology and value addition. The document is presented with an executive summary to elicit the research achievements of the Centre followed by chapters under different heads. I am sure that the initiatives will form the base for strengthening research activity and opening new vistas in banana research in India.

I am grateful to Dr. Mangala Rai, Secretary, DARE and Director General, ICAR, for his valuable guidance and Dr. Gautham Kalloo, Dy. Director General (Hort.), ICAR for his inspiration and encouragement. I also extend my sincere thanks to Dr. S.N.Pandey, Asst. Director General (Hort.), ICAR for his critical suggestions. I am also thankful to all the Scientists of NRC Banana, for their input and help rendered in preparing this manuscript.

(M.M.MUSTAFFA)

Director

EXPLANATIONS TO THE ABBREVATIONS

APEDA	:	Agricultural Produce Export Development Agency
BAPNET	:	Banana and Plantain Network
BARC	:	Bhabha Atomic Research Centre (Mumbai)
BBMV	:	Banana Bract Mosaic Virus
BBTV	:	Banana Bunchy Top Virus
BSV	:	Banana Streak virus
CIRAD	:	Centre de Cooperation Internationale en Recherche Agronomique Pour le Developpement (France)
CMV	:	Cucumber Mosaic Virus
CNMF	:	Centro Naconal de Pesquisa de Mandiocae fruiticultura (Brazil)
CORBANA	:	Corporacion Bananaera Nacional (Costa Rica)
CV	:	Cultivar
DBT	:	Department of Biotechnology (New Delhi)
DNA	:	Deoxyribonucleic Acid
DST	:	Department of Science and Technology (New Delhi)
ELISA	:	Enzyme Link Immunosorbant Assay
FAO	:	Food and Agricultural Organisation
FHIA	:	Foundacion Hondurena de Investigacion Agricola (Honduras)
FYP	:	Five year plan

HACCP	:	Hazard Analysis Critical Control Point
ICAR	:	Indian Council of Agricultural Research (New Delhi)
IIHR	:	Indian Institute of Horticultural Research (Bangalore)
IITA	:	International Institute of Tropical Agriculture (Nigeria)
IMTP	:	International Musa Testing Programme
INIBAP	:	International Network for the Improvement of Banana and Plantain (France)
IPGRI	:	International Plant Genetic Resource Institute (Rome)
IPR	:	Intellectual Property Right
IRC	:	Institute Research Council
ITC	:	International Transit Centre (Belgium)
KUL	:	Katholieke Universiteit Leuven (Belgium)
KVK	:	Krishi Vigyan Kendra
LAN	:	Local Area Network
MAS	:	Molecular Assisted Selection
NABARD	:	National Bank for Agricultural and Rural Development
NARS	:	National Agricultural Research System
NATP	:	National Agricultural Technology Project
NBPGR	:	National Bureau of Plant Genetic Resources (New Delhi)
NGO	:	Non-governmental Organisation
NHB	:	National Horticultural Board (Gurgaon)
NHM	:	National Horticultural Mission (New Delhi)
NRCB	:	National Research Centre for Banana (Tiruchirapalli)

PCR	:	Polymerase Chain Reaction
PGPM	:	Plant Growth Promoting microorganisms
PGPR	:	Plant Growth Promoting Rhizobium
QDPI	:	Queensland Department of Primary Industry (Australia)
QRT	:	Quinquennial Review Team
RAC	:	Research Advisory Committee
RAPD	:	Random Amplified Polymorphic DNA
RFLP	:	Restricted Fragment Length Polymorphism
RNA	:	Ribonucleic Acid
RTPCR	:	Real time Polymerase Chain Reactors
SAU	:	State Agricultural University
SHG	:	Self Help Group
SSR	:	Simple sequence repeats
TBRI	:	Taiwan Banana Research Institute
TC	:	Tissue culture plants
TNAU	:	Tamil Nadu Agricultural University (Coimbatore)
UK	:	United Kingdom
USA	:	United States of America
WTO	:	World Trade Organization

EXECUTIVE SUMMARY

The National Research Centre for Banana (NRCB) was established at Tiruchirapalli, Tamil Nadu on 21st August, 1993 to strengthen the basic and strategic research and to improve the production and productivity of banana in India. Owing to its richness and diversity of cultivated bananas and plantain, Tiruchirapalli was selected as the location for the Centre. The Centre is having 90 acres land for conducting field research activities. The Centre has good infrastructural facilities like library, ARIS Cell, exhibition hall, green houses, quarantine lab and net houses. The laboratory cum administrative building, staff quarters in the city were built during 10th Five year plan.

Crop Improvement

Indigenous and exotic accessions totaling 1025 are being maintained in the field gene bank. This banana germplasm bank is one of the largest in the world. Banana wild and cultivated accessions were collected from the major centers of diversity through 8 explorations in all the regions of India. The genomic status of collected accessions has been assigned. Presently 114 AA, 61 AB, 33 BB diploids accessions, 136 AAA, 229 ABB, 224 AAB triploid,, 12 each AAAA, AAAB, 5AABB, 9 ABBB, 2AAAh tetraploid accessions and 8 Fe'i bananas are grouped and maintained. Around 300 accessions could not be assigned their genomic status. The collected germplasm has been narrowed down to 310 by eliminating the synonyms using morpho-taxomic and molecular markers, viz. RAPD and SSR. Diversity analysis has been done for AB and AAB (Silk) accessions. Three promising selections have been identified and evaluated for their performance in different locations. NRCB-Selection 1 has been released as UDHAYAM for cultivation. This is a high yielding, tolerant to Sigatoka and nematodes and a selection from Pisang Awak clone. Among the accessions available, 92 accessions are highly resistant and 25 resistant to Sigatoka leaf spot diseases. Under IMTP trials, wilt, Sigatoka and nematode resistant clones were identified. A protocol with modified MS media without growth regulators for embryo culture has been standardized for Pisang Awak (ABB), Bluggoe (ABB), Pome (AAB), Wild Musa *balbisiana, M.nagensium* and *M.ornata*. The procedure for ex-plant collection in field was standardized with initial decontamination with mercuric chloride and culture initiation after 48 hours. 12 hybrids developed are being evaluated under field condition.

Embryogenic cell suspensions for Nendran and Ney Poovan have been developed. In addition to NRCB field gene bank, a satellite gene bank and breeding block has been established at Agali, Kerala.

Crop Production

Application of 25% N as FYM + 50% n as neem cake + 25% N as inorganic fertilizer increased the yield by 20 per cent coupled with least nematode infestation in Rasthali, Poovan, Robusta, Monthan and Karpuravalli cultivars. Application of organic sources reduced the time taken for flowering, maturity and total crop duration in all cultivars. Weed free conditions in Karpuravalli banana up to 6 months after plating was critical for growth and yield of banana. Weed free conditions up to 9 months gave an additional income of Rs.26600/- in Karpuravalli banana. Plants (2250 pl/ha) with 20 litre water/ day/ plant +75% N (150g N/pl) as fertigation recorded 20% increase in yield with maximum net profit and a benefit cost ratio of 1.96 in Poovan banana.

A combination of distillery sludge 2.5 kg + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure $plant^{-1}$ recorded the maximum growth parameters in Rasthali and Karpuravalli bananas. It also significantly suppressed the root population of root lesion nematode, root knot nematode and spiral nematodes. The organic manure applied plants had less incidence of Sigatoka leaf spot diseases while the inorganic treatment had severe incidence of leaf spot diseases. Application of gypsum @2kg/plant +FYM 15 kg/plant +120% recommended K produced an increase in yield by 51% over control in saline sodic soil in Nendran and Rasthali banana. Application of 15 kg rice husk ash or 15 kg poultry manure per plant resulted in an additional profit of Rs.23,750/ - ha and Rs.34,250/ha respectively in Poovan banana. Paired row planting system with 4500 plants per ha increased the productivity and fruit quality with 75 percent recommended fertilizers dose as fertigation in Robusta, Grand Naine and Red banana. 8 drought tolerant accessions were identified based on leaf water retention capacity.

Post harvest technology

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bananas. Several value added products like Flower thokku, peel thokku, fruit pickle, fig, biscuits, jam, ready to serve beverages and functional fruits like chapathi, bread and health drink have been developed. Many of these technologies have been commercialized.

Crop Protection

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yield by 63 per cent. Anthracnose disease of banana was controlled by spraying 25% per cent leaf extracts of *Solanum tarvum*. *Trichoderma viride* (10^9 / ml), *Pseudomonas spp*. (10^6 / ml) Bacillus spp (10^6 / ml) and Propiconazole (0.1 percent) spray were also effective in controlling the disease. Three applications of *T..harzianum, P. flurescence* and *B.subtilis* at 10 g per plant at the time of planting, 3 and 5th month after planting reduced the wilt incidence. *P.aerogonosa* and *P.viridiflavus* were effective in controlling crown rot diseases.

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1. PREAMBLE

1.1 Mission

Banana is the most important fruit crop in India and accounts for 31.7 per cent of the total fruit production. It is widely cultivated in varying agro-climatic regions under different systems of production. The banana research in India is directed towards increase in production and productivity. However, banana cultivation continued to face several pests and diseases problems which have affected the production and productivity. Nevertheless, conservation and characterization of genetic diversity, improvement of cultivars resistant to biotic and abiotic stresses, production technology for high productivity with good quality fruits and post-harvest technology needed more systematic

research. The growing awareness of banana in human nutrition, high economic returns per unit area, export potential and production constraints due to biotic and abiotic stresses have warranted systematic research in banana.

Production and productivity in banana is confronted with various biotic and abiotic factors. The production constraints also vary from region to region however many problems are similar in nature. The complexity of problems needs basic, strategic and adaptive research to attain maximum production and productivity in banana with an interdisciplinary and holistic approach without affecting the existing ecosystem.

The **National Research Centre for Banana (NRCB)** was established at Tiruchirapalli, Tamil Nadu on 21st August, 1993, based on the recommendation of a high level task force committee to address the production constraints in banana to achieve high production and productivity through basic and strategic research approach in banana, which started functioning effectively from 1st April, 1994.

1.2 Vision

The vision of the National Research Centre for Banana (NRCB), Tiruchirapalli is to increase the production and productivity and to sustain the growth achieved during the last two decades. During the last two decades in banana, area expansion and production has registered a 209 % growth, which was mainly due to the adoption of improved high yielding varieties and production technologies. However, the average national productivity is far below the productivity obtained in some states, which is due to production constraints in those banana growing regions. The priority is, these constraints need to be addressed in systematic and multidisciplinary approaches for improving the productivity per unit area. To achieve a projected target of 25 million tons of banana and an annual per capita consumption of minimum 15 kg banana fruits in 2020 AD is the vision of the Centre.

2. MANDATE

The Centre was established with the following mandates:

- To undertake basic and strategic research for developing technologies

to enhance productivity and utilization of banana.

- To develop improved cultivars through traditional and biotechnological methods and conserve the diversity.
- To serve as national repository of germplasm and information related to banana and plantain and also to disseminate the knowledge for production and productivity.
- To provide leadership and coordinate the network research for generating location specific varieties, technology and for solving specific constraints of banana and plantain production.
- To collaborate with relevant National and International agencies in achieving the above objectives.

2.1 REVISED MANDATE

With the change in the objectives and functions in the era of WTO and IPR regime, there is a need to modify the mandate of the Centre. Accordingly, the revised mandate of the Centre would be as follows:

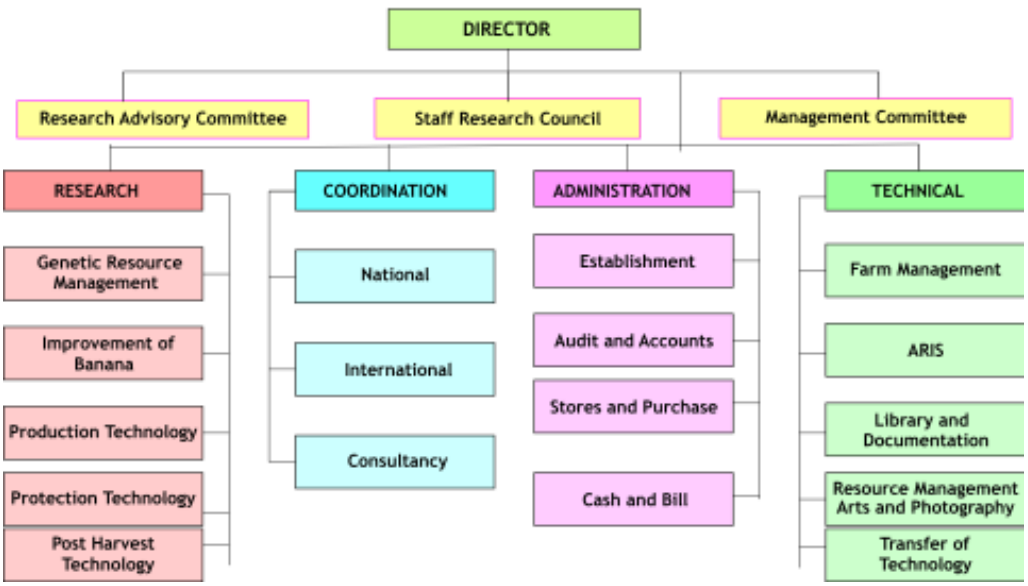
- To undertake basic, strategic research, developing technologies to address specific constraints, to enhance the productivity in banana
- To develop improved cultivars through classical and biotechnological approaches
- To serve as a national germplasm repository for banana and plantain, and to conserve and document the genetic diversity
- To develop location specific varieties, improved production technology and post harvest technology including value addition for maximizing the profitability
- To solve major biotic and abiotic production constraints in banana and plantain
- To disseminate the knowledge for increased production and productivity

- ❖ To provide leadership, coordinate the network research and to collaborate with National and International agencies in achieving the above objectives

3. GROWTH

National Research Centre for Banana was started in 21 August, 1993 and presently with 15 Scientists and has a total staff strength of 47. The main objective of NRCB is to conduct basic, strategic and adaptive research for improving the production, productivity and utilization of banana. Currently the Centre's research activity is functioning under 4 mega areas viz., Crop Improvement, Crop Production, Crop Protection and Post harvest management. Scientists are involved in multi-disciplinary research approaches to solve the problems faced by the banana farmers in the management of pests and diseases, production technology and value addition. The Centre is coordinating and collaborating with various national and international agencies in formulating various activities to address the problems in banana production. In addition, it is also involved in consultancy services and training programmes to increase

ORGANOGRAM



the capacity building of stake holders, private partnership and entrepreneurs' development. The organizational set up of NRCB is given in Fig.1.

3.1 Infrastructure

The Centre has established its laboratory and administrative building (2222 sq. m) built at a cost of Rs.200 lakhs. The building has laboratories for genetic management, crop improvement, molecular biology, tissue culture, nutrition management, water management, soil and leaf nutrient studies, physiology and biochemistry, post harvest, entomology, nematology, pathology and virology. In addition, it is having facilities like ARIS, quarantine laboratory, glass house, green house, net house, National gene repository etc.

3.1.1 Land

The area available for field experimentation is 38 ha. The farm is having three bore wells and three open wells. In addition, the land is irrigated by the "New Kattalai Canal", from Cauvery River.

The soil of NRCB farm is classified taxonomically as fine, mixed, hyperthermic, *Typic Haplustepts*. The texture is silty clay loam. The average particle and bulk densities are 2.30 and 1.25 mg/m^3 respectively. The average porosity is 45.6 per cent. The drainage is low to moderate. The pH ranges between 7.5 and 9.5.The Electrical Conductivity ranges between 0.1 and 0.6 dS/m. The Organic Carbon varies between 0.1 and 0.5 per cent. The Cation Exchange Capacity ranges between 10 and 20 cmol (p+) kg^{-1}.

The Centre is also having a satellite germplasm block in 2.0 ha land at Agali (Kerala), which is 20 km from Coimbatore belongs to Sugarcane Breeding Institute, Coimbatore .

3.1.2 Library

The library has 645 books, 34 periodicals consisting of 27 Indian and 7 foreign journals, 50 dissertations and 88 reports. An ARIS cell was established in 1997 with LAN and window server and one workstation funded by NATP (ARIS), New Delhi. Duplicating machine, fax machine, photocopier, computers, EPABX and printers were part of the modernization of the office. In addition, photocopier, computers, Internet facility and LAN facility have been provided

for the use of the Scientists for better accessibility to the literature sources nationally and internationally.

3.1.3 Equipments

The laboratories are modern, functional and are having sophisticated equipments which are being utilized effectively for the day to day research activities. The Centre is having the laboratory equipments viz., Spectrophotometer, Elisa Reader, Microscope, Plant canopy analyzer, Atomic Absorption Spectrophotometer, Osmometer, Soil Moisture Meter, Electrical Orbital Blot Double Decker, Gel Dryer, Trinocular Research Microscope, Horizontal Autoclave, LCA-4, Polymerised Chain Reactor, Image Analyzing system, Lyophilizer, Semi dry apparatus

The physical facilities viz., Packing house, Quarantine laboratory, Ripening room, Tractor shed, Automatic Weather Station, Generator room, Net house, 25 KVA Diesel Generator, Tractors, Power tiller, Paddy Thresher and Over-

Head	2002-03	2003-04	2004-05	2005-06	2006-07	Total
PLAN	95.40	159.12	199.99	202.60	47.65	771.41
NONPLAN	87.00	110.10	122.00	168.00	144.00	631.10

head tank have been developed during the last two plan periods.

PLAN	SCIENTIFIC	TECHNICAL	ADMINISTRATIVE	SUPPORTING
X	15	15	9	7

3.2 Budget

3.3 Manpower

4. SALIENT RESEARCH ACIEVEMENTS

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5. IMPACT ASSESSMENT

NRCB with its 13 years of existence, it has made severe impact on many areas viz.;

1. Germplasm conservation
2. Micro-irrigation and fertigation in banana
3. Tissue culture plants certification and cultivation
4. Integrated pest and diseases management
5. Virus indexing and certification of mother tress and TC plants
6. Processing and value addition in banana and technology transfer for commercialization

The Centre has made concerted efforts to collect the available wild and related Musa spp. from the hot spots and also from the Centers of diversity for banana like North East regions of India consisting of Assam, Arunachal Pradesh, Nagaland, Meghalaya and Manipur districts, Andaman and Nicobar islands, Western ghat and Eastern ghat region like Arakku valley. Due to these efforts, 12 wild species of Musa including Rhodochalamys have been collected and evaluated for its resistance to major biotic stresses. The species / accessions are good source for resistant genes and are being used in the breeding programmes.

The technology on micro propagation and fertigation in banana has created a greater impact among the farmers in conserving the scarce commodity water and fertilizers. The technology adoption has resulted in 30-40% water saving and 25-30% fertilizer conservation, thereby the environmental pollution, better water use and fertilizer use efficiency was achieved.

The Centre has developed 15-16 value added banana by-products and has

commercialized 5-6 value added products and is being available in the market. By adapting these technologies, the farmers can turn to an entrepreneur and can generate rural employment for improving the living standard of stake holders and banana farmers. The value addition technologies is becoming popular and training are offered to the interested farmers, entrepreneurs, NGOs, SHG and KVK staff members belongs to different states thereby the technology is disseminated. NRCB in collaboration with NABARD, three village clusters have been adapted for such training to the SHG farmers.

The development of integrated pest and disease management has lead to the adoption of various bio-control agents like *Trichoderma viride*, *Pseudomonas fluroscens*, *Paecilomyces lilacinus* for the control of weevil, nematodes, pathogens like Fusarium, *Botryodiplodia* etc. could be useful in the control of pest and diseases. Virus indexing and testing of mother and TC plants has helped the tissue culture industries in different states, to produce healthy true to type virus free mother suckers and Tissue culture plants for the farmers. This has made a great impact among the farmers in getting disease free, true to type healthy plant for successful establishment and heavy yield.

5.1 Growth

Banana and plantain is the 4th important food commodity at global level and it is largest fruit crop in terms of production in India. There has been a significant exponential growth in area and production of banana both at national and international level during the last three decades, International concern for banana and plantain in last 10-15 years has resulted in the creation of INIBAP. Significant progress has been made in conservation of *Musa* wild and cultivated germplasm from the center of diversity has lead to identification of improved cultivars resistant to diseases. Advancement in

in vitro conservation, *in-vitro* propagation and use of biotechnological tools for molecular characterisation and exchange germplasm among the banana growing countries with international organisation has lead to global cooperation for evaluation of global hybrids against major biotic stresses like wilt, nematodes and leaf spot diseases. The growing global co-operation in the south East Asian countries has resulted as a regional network programme namely BAPNET for closer co-operation and co-ordination.

Growing of banana and plantains have historical, geographical and cultural richness equal to any of the world's major crops and its importance for millions of people is beginning to achieve the recognition it meant, which is reflected with the increasing research efforts being devoted to this crop.

Currently per capita consumption of banana is to the tune of 10.5 kg annually which has to be increased to 15.0kg in the year 2015. National productivity is much below the potential which has been obtained in some states like Maharashtra and Tamil Nadu. Thus, increased production and productivity has to be achieved through efficient harnessing of resources through enhanced research capability directed towards improved productivity.

5.2 Input-Output Assessment

The National Research Centre for Banana has significantly contributed for banana development. The Centre has developed new technologies on improvement, production, protection and post-harvest management in banana. NRCB has disseminated its new technologies to the farmers and entrepreneurs and has been adopted widely by the farming community. All the technologies and trainings have considerable impact on the improvement of rural economy by generating rural employment.

Banana being a long duration crop (11 to 15 months), the lag period for adoption of new technologies for banana will require approximately six years. The input-output assessment should cover the economic impact assessment (including adoption studies, economic studies i.e., returns to investment etc.), social impact assessment (including studying the effects of new technologies on poverty, gender issues, food security, employment, cash flow, income, rural-urban migration etc.) and the environmental assessment (including studies on pollution, sustainability, natural resources etc.).

Transfer of technology of value added products like banana fig, juice, pickle, thokku to the small scale entrepreneurs and self help group has resulted in the development of cottage industry on the above products. The trainees have already started larges scale production and marketing of banana fig and juice. Banana juice is now being produced by simple techniques of enzyme separation and supplied without any preservatives for immediate use in marriage functions. This has improved the economic background of many of

the trainees. Pickle and pulp industry are in the offing based on the NRCB technology.

The improved technology on high density planting coupled with drip irrigation is now adopted successfully by many farmers, resulting in reduction in the cost of production with enhanced income from unit area.

The simple technique of setting banana stem traps for control of stem borer has saved crop loss more than 20%. This simple technique is being followed extensively in the endemic areas. Some of the landless laborers have taken up setting up of this trap on contract basis and are getting good income.

The Centre is without a social scientist and hence the correct assessment of impact may be difficult. This needs to be strengthened for dissemination of technologies mid-term correction, feedback and impact assessment.

5.3 Gaps and short comings

The farmers face major problems such as non availability of good quality and disease free planting material. There is a need to double the requirement of planting material by next 5 years. Thus, the requirement of banana suckers and tissue culture plants would be approximately up to 1000 million plants. Indiscriminate application of inorganic fertilizers has lead to nutritional imbalances and affecting the substrate dynamics of the banana growing soils. Lack of awareness to increase the fertilizer use efficiency in banana through Integrated Nutrient Management System, fertigation, split application, nutrient assimilation pattern and importance of micronutrients in banana cultivation. The proper infrastructure facilities like cold storage, processing facility (primary and secondary) for long term storage the produce is lacking. Marketing is a major post harvest problem faced by the farmers. In most cases, the banana farmer often fails to get the remunerative price for his produce. Region specific markets are to be developed keeping the perishable nature of the fruit. Providing training to farmers, entrepreneurs and self help group members on value addition for generating additional income and rural employment. Successful management of resources in sustainable manner to meet the need of growing population without degrading environment should be the major issue for banana research.

Various issues have to be addressed by initiating systematic approaches in

basic and strategic front line thrust areas like genetic engineering, genomic, molecular characterization using advanced techniques, somatic embryo genesis, selection of useful somaclonal variants, high density planting, fertigation, precision farming, organic farming, integrated nutrient management, micro – nutrient management, integrated pest management, integrated disease management, use of bio-agents and botanicals, value addition and better handling and storage studies.

The thrust of NRCB will be for basic and strategic research including genomic, molecular genetics, genetic engineering and biotechnological approaches to address the breeding constraints should be one of the thrust areas. Immediate attention could be to address the production technology constraints, cultivars identification for higher productivity, efficient water management, fertigation, clump management have to be focused to increase the production and productivity with a reduction in cost of cultivation. With the growing awareness on the environment and ecosystem, there should be technology available for the efficient management of important pests, nematodes, fungal, bacterial and viral diseases using eco-friendly integrated management, bio control and botanicals. To generate additional income and to over come the marketable glut in the harvesting season value addition of banana and processing of banana in to different byproducts needs a special attention.

To improve the capacity building and to increase the competence, the scientists have to be well equipped in the front line research areas and to carry out the research in these areas sufficient infrastructures have to be developed.

In addition collaboration with national and international agencies, which are working on banana, should be strengthened to have an effective close interaction. Training programmes for the benefit of the state departmental extension workers and banana farmers has to be strengthened for rapid dissemination of the technologies developed by the Centre. For faster and effective transfer communication infra-structural facilities on advanced information systems has to be developed.

To achieve the optimal output on the priority thrust areas and to have a sustainable production, liberal funding is essential. Adequate financial support should be provided for conducting exploration, survey work to develop cartography and to identify the co-evolution of species and pathogens.

5.4 Lessons learnt, Suggestions and Options for Future

The production and productivity in banana during the past 2-3 decades has faced a tremendous growth in India and also at global level. To meet the large demand of the planting material, micro propagation techniques became popular with lot of private tissue culture companies dominating as main players in the field. Due to large scale multiplication and without quality certification, there were lot of complaints about the genetic fidelity, quality, disease freeness and free from somaclonal variation. This has lead to a decline in the adoption of the new technology among the farmers. This situation warranted a new legislation to certify the planting material produced by the companies and also certification of the tissue culture companies in banana trade.

Due to indiscriminate and non-use of disease free quality planting material has lead to a situation that new diseases like bacterial head rot, pseudostem weevil, nematodes, fruit scarring beetle and bract mosaic viruses are spreading to non-traditional areas where banana is grown for the first time. This warranted a systematic approach in the movement of planting material from traditional banana growing areas to non-traditional banana growing areas. An quarantine legislation is needed to curtail the movement of diseased suckers from affected areas.

The demand to increase the production and productivity has lead to indiscriminate use of inorganic fertilizers at the cost of organic fertilizers. This situation has lead to the depletion of organic matter in the soil affecting the soil health, soil micro flora. Soil, water pollution and depletion of micro nutrients availability. This has created less productivity in the long run causing a plateau in static productivity. Due to greater awareness about the organic banana in the west, there is a change to grow banana organically for better

quality fruits without inorganic fertilizers and pesticides usages. Therefore, research approaches and new initiatives at NRC Banana have been directed to develop a technology for organic banana production and also use of bio-fertilizers and natural alternate resources effectively for better soil health, substitute for inorganic fertilizers and use of micronutrients. Though, food security has been achieved in banana, there is a felt need to improve the nutrition security in banana and plantains.

Similarly, use of harmful pesticides and fungicides for the control of major pests and diseases has created soil and environmental pollution affecting the soil, water and ecosystem. This has warranted concerted efforts at research priorities at NRC banana in developing integrated pests and disease management strategies involving use of bio control agents, botanicals, and beneficial micro organisms for the control of soil borne pathogens and other pests and diseases. This has opened a new vista of research priorities in use of beneficial bio-control and micro-organism for the control of harmful insects and pathogens and also improving the plant growth and yield in banana.

Banana being a highly perishable crop and also susceptible to vagaries of weather conditions, the post harvest losses are estimated around 25-30%. Being a seasonal crop, to get a better price during the glut season, processing and value addition play an important role storage, marketing and price realization. The NRC Banana has developed 15-20 value added products in banana and plantain utilizing fruit, pulp, peel, flower, unripe fruit etc. The technologies have been transferred and are being adapted commercially in different parts of the country for better marketing and profit. In addition, the fibre extracted from the pseudostem also has great potential in the local and export market.

Though, India is the largest producer of banana, the quantum of export is very negligible due to the small holdings and non-availability of produce throughout the year in large quantity. The technology in handling, harvesting, transporting, storage, shipment, artificial ripening and packaging needs attention for the export trade and NRC Banana has developed the technology for export of banana in Cavendish group of bananas and also in other traditional yellow bananas grown in India which can be exported to Middle east, South east Asian countries and European market where the Indian ethnic population is more. This area needs more attention in popularizing the India varieties in

6. SCENARIO AND SWOT ANALYSIS

6.1 SCENARIO

6.1.1 National Scenario

In India, banana and plantain are widely grown in both tropical and subtropical regions comprising Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Orissa, Bihar, eastern U.P., West Bengal, Assam and North eastern states with considerable socio-economic and cultural importance. Banana is the largest fruit crop accounting for 31.7% of total fruit production from 12.6% arable area with a total production of banana, estimated as 16.9 million tons /annum from 4.9 lakh ha. Most of the production is consumed internally with a meager share of 0.1% as export.

There has been a significant increase in production of banana during the last 25 years while the last decade has witnessed a steep growth due to banana research and development. The area has increased from 2.0 lakh ha in early 70's to 4.9 lakh ha in 2000's, while banana production has taken a giant leap by 500% from 3 million tons to 16.9 million tons (Table). The productivity has also increased from a meager 9 tons to 32.5 tons, while in some states; the productivity is as high as 50 tons. This significant increase in the production and productivity of banana is due to various research and development activities in banana and plantain. This could be achieved due to availability of high yielding genetic material especially Dwarf Cavendish group of bananas, improved production system and adoption of efficient protection technologies for the control of major pests and diseases under different climatic conditions have contributed to the fast growth of banana industry in the country.

Growth of Banana Industry in India

Year	Area (Million ha)	% Increase	Production (Million Tons)	% Increase	Productivity (tons/ha)
1962	0.20	---	2.6	---	11.5
1977	0.24	48.0	5.9	153.4	15.54
1987	0.30	150.0	8.9	255.0	17.42
1993	0.43	215.0	11.9	457.0	27.57
1997	0.44	220.0	13.33	512.0	29.7
2000	0.49	245.0	16.81	696.0	34.3

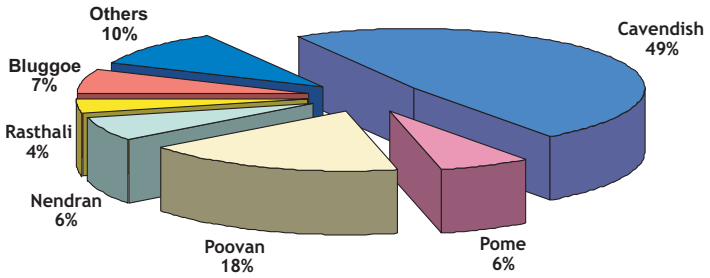
India is home of wide range of *Musa* cultivars with varying genomic status with diverse agro-climatic conditions, which has encouraged the development and sustenance of large number of varieties catering to local needs. Though, more than 20 varieties have been grown commercially, Cavendish groups form the main stay of Indian banana Industry, owing to its high yield, wide market acceptability, short crop duration and high economic returns per unit area. Poovan is another cultivar grown commercially in different regions for its wider adaptability and tolerance to drought and diseases. Rasthali is grown in some specific regions due to its premium price in the market. Ney Poovan is also grown commercially in many parts of the country. Virupakshi, Monthan, Karpuravalli and Chakkia varieties are also grown to a large extent in some states. Nendran is specially grown in Kerala and Tamil Nadu due to the local preference. The varietal situation prevailing in different states/ regions indicated the regional adaptation, sustainability and preferences. The area, production and productivity of the banana in different growing states are provided in Table.

State wise area, production and productivity of banana in India

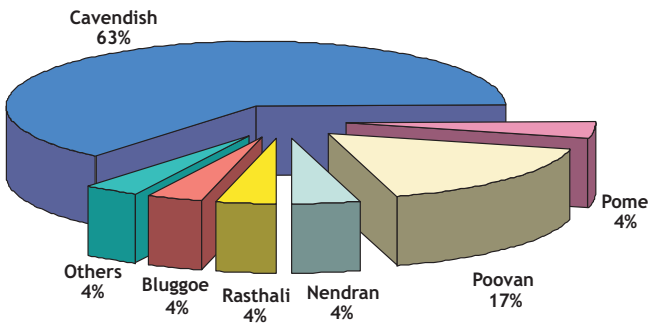
States	Area (ha)	Production (T)	Productivity (T/ha)
Andhra Pradesh	48,500	12,12,500	25.00
Assam	41,922	5,83,383	13.92
Bihar	29,196	5,83,920	20.00
Gujarat	34,201	11,09,069	32.43
Karnataka	61,031	20,15,013	33.02
Kerala	27,914	3,93,720	14.10
Maharashtra	72,175	43,30,500	60.00
Madhya Pradesh	23,860	9,65,375	40.46
Orissa	16,350	1,93,540	11.84
Tripura	4,033	27,400	6.79
Tamil Nadu	92,158	48,56,416	52.70
West Bengal	18,810	3,31,400	17.62
Others	20,278	2,09,922	10.35
Total	**4,90,428**	**1,68,12,158**	**34.28**

Source: National Horticulture Board, Year Book - 2002

Area (%) of different cultivars in India



Production(%) of different cultivars in India



Though, India's production is 16.9 million tons of banana and plantain per year, the extent of post harvest losses is about 20-24%, amounting to a loss of around 3 to 4 million tons of fruits valued about Rs.3000 crores per annum. This losses are basically due to faulty handling procedures like improper transportation, lack of packaging, cold chain and post-harvest storage infra-structural facilities.

The export of banana from India is negligible while a small quantity of plantains (Nendran type) is exported to Gulf countries mainly from Kerala and southern Tamil Nadu. Recently, attempts have been made by Maharashtra and Tamil Nadu farmers for export of Robusta banana to Gulf countries.

In the banana processing sector, only 3-4% of the total production is processed. The banana processed products mainly consists of banana chips which is produced to a tune of over one lakh tons a year. Majority of the chips are produced from Nendran banana, however, Robusta and Monthan banana fruits are also being processed as chips to some extent in Maharashtra and Tamil Nadu states. Other products popular in the market are banana puree and powder.

6.1.2 International Scenario

Banana and Plantain is the 4th important food crop in terms of gross value. It is produced in 130 countries in tropical and sub-tropical regions of the world of mostly developing economies. Globally, banana and plantain are cultivated 8.834 million hectares with a total production of 100 million tones. In most of the banana and plantain growing countries, it is grown perennially with single or two cultivars dominating the whole economy. Due to the tropical nature, these countries are receiving plenty of rains with good soil; the perennial system of cultivation is followed in large areas. Due to the non-availability of labour, mechanization is commonly adapted with aerial spraying for plant protection measures. In the banana republic countries, Cavendish group of bananas are grown commercially for export to USA and UK markets. In South American countries like Brazil etc., pome group of fruits are the most important type grown commercially in large areas. In the Western African countries, Plantain is the most preferred variety grown for local and export trade. In the eastern African countries, high land AAA bananas are commonly grown with Cavendish and cooking bananas.

In the South East Asian countries, like India, polyclonal system of cultivation is adopted for local and export market. In this region, Philippines, Indonesia and Malaysia are the major banana growing countries while Australia, Cavendish banana are grown in a larger extent. The area and production of top 10 banana and plantain growing countries is presented below.

International status (area, production, productivity)

Country	Area (million hectares)	Production (million tonnes)	Productivity (tonnes/ha)
India	0.490	16.81	34.30
Ecuador	0.298	8.03	26.94
Brazil	0.513	5.74	11.18
China	0.259	5.40	20.84
Philippines	0.400	5.06	12.65
Columbia	0.444	4.20	9.45
Indonesia	0.285	3.60	8.14
Costa Rica	0.054	2.32	42.96
Cameroon	0.312	2.25	7.21
Mexico	0.074	1.97	26.62
Others	5.705	41.77	7.32
Total	**8.834**	**97.15**	**10.99**

Banana and plantain consumptions were maximum in African countries with 40-45 kg/year / individual as against 10.5 kg/year in India. Banana and plantain are the main staple food in East and West African countries. Most of the plantains grown in West Africa is export to France and European markets. Thus banana and plantain cultivation forms the food security of the millions of people and also sustenance of the small and marginal farmers in African and Asian countries.

Due to the different in the system of cultivation and varieties grown, the scenario of the biotic stresses also varies influencing the production and productivity in the region. Due to monoculture system of Cavendish group of varieties cultivation, leaf spot disease management is th3e prime constraint in the banana republic and South American countries which may require 25-30 rounds of aerial spraying of fungicides. But in Asian and South East Asian countries, many biotic stresses like Fusarium wilt, weevil, nematodes and viruses are the major limiting factors in the production. In the African countries, the Moko disease is becoming more serious concern in the production of high land and plantain and cooking bananas which form the main staple food in the region.

Various research activities in different regions of the world are coordinated and facilitated by the International Network for the Improvement of Banana and Plantain (INIBAP) located in France. The Banana and Plantain Network (BAPNET) located in Philippines coordinated the banana research activities carried out by the National Agricultural Research System (NARS) of Asia and South East Asian countries.

These organizations are established with a commitment for the improvement in production and productivity of bananas and plantains by global partnership in the areas like germplasm exchange and conservation, crop improvement, biotic and abiotic stress management.

6.2 SWOT ANALYSIS

6.2.1 Strength

India being one of th4e centre of diversity and one of the hot spot for the wild *Musa* species and other wild relatives of *Musa* is the latest strength for banana conservation activities. In addition, India has the largest diversity especially BB and ABB genome, which are the gene sources for resistance to biotic and abiotic sources. *Musa acuminata* ssp. *burmannicoides* (Calcutta-4) is one of the wild species which originated from India is the most common gene donor for inducing resistance to leaf spot diseases developed by Honduras. The exploration conducted in the North East region has yielded many wild bananas and wild relatives which are potential gene donors for many biotic and abiotic stresses. Since the pathogens also coevolved with wild species in the centers of diversity, India being one of the hot spot of diversity has the potential gene donor for most of the biotic and abiotic stresses which can be utilized in the breeding program for evolving hybrids. The centre has collected all the available land races, accessions wild and related species from all over the world and also from India, which are conserved in the field gene bank which could be further exploited in the breeding program. In India, since polyclonal system is followed, in varying growing system under the different climatic conditions, make banana and plantain production free from sudden out break of diseases and viruses and also break down of resistant which have been observed in the monoclonal system of planting of Cavendish group of banana.

Due to the availability of different varieties of banana and plantain through out year and growing awareness of bananas in nutritional and medicinal values have encouraged the export of non-traditional banana varieties other than Cavendish banana. The intensive cultivation practices with higher productivity and availability in different regions could be strength for the export of bananas through out the year from different regions of cultivation.

6.2.2 Weakness

India being the largest producer of banana in the world, and the average productivity is less as compared to the states which have recorded the maximum productivity of 60-70 tons per / hectare. This is due to growing of low-yielding local cultivars and non-adoption of improved production and protection technologies. Regional problems and consumer preferences have also contributed for low productivity. Non availability of high yielding cultivars other than Cavendish group with resistance to wilt is one of the major constraints of production. In addition, biotic stresses like wilt and leaf spot diseases, nematode and viruses for the major threats in reducing the productivity and also sustainability. No concerted efforts have been made to evolve improved varieties which are resistance to these biotic stresses so that the productivity can be improved with minimum cost.

The post harvest losses are estimated to be 20-30% which accounts for 200-300 crores monetary loss. The land holdings are being small the farmers could not adopt the better post harvest handing methods so that these losses could minimized. In addition, infrastructure facilities like cold storage, reefer van facility for transportation and better marketing facilities are needed to minimize the losses. The one of the greatest dis-advantages in banana marketing is not getting remunerative prices during the glut seasons. The farmers are forced to sell at through-away prices due to its perishable nature. Development of value addition is one of the weaknesses areas which need further strengthening and commercial exploitation. Commodity specific markets are not available which one of the weaknesses is in the marketing links.

6.2.3 Opportunities

India being a tropical and semi-tropic region, banana can be grown in any season and the fruits will be available through out the year. This provides an

opportunity for export of banana to the foreign markets through out the year. India, being close to Gulf and Japanese markets, the organic banana can be exported profitability since banana is cultivated in most of the states with minimum fertilizers especially in North East regions. Due to the adoption of the polyclonal systems different varieties of banana and plantain are available for export due to the preference of the ethnic Indian population in these countries. Due to the varying production systems and regional peculiarities provides opportunities for the cultivation of bananas from coastal region to hill region up to an elevation of 1200 meters by which production constraints can be manipulated. Similarly high genetic diversity can provide an opportunity for selection of superior clones from the population. After the WTO regime and opening up of the banana trade, there is an enhanced opportunities for export of banana to UK and US markets due to cheap production cost and availability organic bananas.

Being a short duration fruit crop and highly remunerative crop, many farmers started growing bananas in non-traditional areas in North India especially in east Uttar Pradesh, Uttranchal and Punjab. Due to the availability of tissue culture plants in large quantity which is free from pests and diseases and viruses, the productivity of these plants are very high thereby the farmers are getting very high profits.

6.2.4 Threats

There is a great threat to the wild Musa species and other related species due to the de-forestation, Jhum cultivation and urbanization in the centre of diversity viz., North Eastern region. Because of this, the valuable genetic resources are lost. To prevent this loss, effective measures should be taken to conserve and document these valuable genetic materials. A national repository has to be identified for conservation of these valuable banana germplasm and has to be characterized for finger printing these materials under the IPR regime.

Major production constraints like insects, nematodes, diseases and viruses are major threats in banana production. Due to the indiscriminate use of infected planting materials there is a threat to spread the diseases in the non-traditional areas also. Planting of diseased planting material continuously has resulted in drastic reduction in productivity and has threatened the

sustainability of banana cultivation. Spread of new virus diseases, insect pests, nematodes and diseases like Erwinia are becoming serious threats in banana cultivation of late.

Import of new varieties by the tissue culture companies without proper quarantine measures at the entry point may lead to introduction of new diseases, races and viruses to India which may threaten the cultivation of bananas and banana industry. These imports should be curtailed so as to avoid these types of dangers.

7. PERSPECTIVE

The production and productivity of banana and plantain recorded a significant increase during the last two decades, which could be accomplished due to the research and development activities done by ICAR, SAUs and state departments. The projection for the year 2020 is to be tune of 25 million tonnes and this goal is achievable due to the availability of improved varieties, production technologies on water management, nutrition management and integrated management of nutrition and water, effective plant protection strategies involving integrated pests and diseases management using bio-control agents, botanicals etc. With better post harvest handling and processing technologies the farmers could get better profit and through value addition, the waste could be converted into by-products like pickles and thokku from banana flowers, immature fruits and peel.

The availability of fruits through out the year, due to the varying climatic and growing conditions in the country has made, India as the major banana producing country in the world. With opening up of the trade and also the growing demand for organic bananas and other than Cavendish group for export purposes has opened up new avenues in the export trade. The ethnic Indian populations in the Gulf and European union has opened up the export trade for Indian bananas. Due to the constraints in tax structure and export tariffs the banana export trade is heavily burdened.

The research priorities should be focused to achieve higher production and productivity with minimum cost of cultivation. With escalation in the input cost like water, fertilizers and quality planting material coupled with plant protection measures for the control of major pests and diseases are the

major limiting factors in improving the production of bananas. To overcome this hurdles the priority should be given to high yielding bananas with resistant to major biotic stresses. To achieve this collection and genetic diversity and identification of resistant gene sources using advanced biotechnological tools should be given importance. Technology for increasing the efficiency for water and nutrient use with better cropping system has to be evolved. To improve the soil health and sub state dynamics, suitable technologies involving integrated nutrient management and organic farming has to be given priorities.

Integrated management of insect pests, nematode and diseases involving biocontrol methods, botanicals, PGPR has to be given priority to safeguard our ecosystem without polluting the environment. With grater awareness about the organically produced bananas in local and export markets, these areas have to receive priorities. To overcome these hurdles, grater importance has to be given in evolving plants resistant to major biotic and abiotic stresses using molecular breeding and genetic engineering techniques incorporating resistant genes from wild *Musa* gene sources. In this regard, highest priority should be given for conservation of the available genetic wild material from the centers of diversity using molecular tools, needs atmost attention in the era of IPR regimes.

With the above perspective in mind, the following thrust areas are identified. To achieve these on a longer perspective plan, the targets are identified accordingly and the programmes are proposed for future research activities at NRC Banana.

7.1 Crop Improvement

7.1.1. Germplasm 0management

- ❖ Enhancement of genetic variability through exploration and introductions.
- ❖ Conservation of germplasm in field and *in-vitro*.
- ❖ Germplasm evaluation for quantitative and qualitative traits and utilization.
- ❖ Morpho taxonomic and molecular characterization of germplasm.

7.1.2 Crop improvement through classical breeding

- ❖ Development of hybrids for yield and resistance to biotic stresses.
- ❖ Evaluation of accessions for male and female fertility.
- ❖ Development of synthetic diploids with superior traits.

7.1.3 Improvement through biotechnological /molecular breeding approaches

- ❖ Incorporation of genes for yield, quality and resistance to biotic and abiotic stresses
- ❖ Development of protocol for embryo rescue and callus induction.
- ❖ *In-vitro* polyploidization of diploids.
- ❖ *In-vitro* screening for biotic and abiotic stresses.

7.2 Crop Production

7.2.1. Production

- ❖ Standardization of agro techniques for increasing production and productivity
- ❖ Development of technology for organic farming
- ❖ Integrated nutrient and water management
- ❖ Cropping system management
- ❖ Micro-nutrient management

7.2.2 Crop Physiology and Bio-chemistry

- ❖ Physiology of flowering and fruit development
- ❖ Biochemical and physiological studies on maladies of unknown etiology

7.2.3. Post Harvest Technology

- ❖ Post-harvest handling and packaging of banana
- ❖ Development of value added products
- ❖ Banana fibre extraction and processing

7.3 Crop Protection

7.3.1. Insect Pest Management

- ❖ Management of major pests of banana and plantains
- ❖ Evaluation and selection of bio control agents

7.3.2. Nematodes management

- ❖ Survey and mapping of nematodes in banana growing regions
- ❖ Role of nematodes on Fusarium wilt complex
- ❖ Antinemic activity of botanicals
- ❖ Development of integrated nematode management

7.3.3. Fungal and Bacterial diseases management

- ❖ Evaluation of botanicals for wilt
- ❖ Bio-control of wilt

7.3.4. Viral diseases management

- ❖ Development of molecular diagnostic kit for the identification of viruses

8. ISSUES AND STRATEGIES

8.1 Strengthening of ongoing research areas

Genetic resources available in banana and plantains are huge and it is suspected that most of them are synonyms, which has to be identified and removed. The clear genetic status of all the collections is very essential for breeding programmes. To overcome these problems molecular characterization of these accessions is essential. The development of molecular markers and marker-assisted selection would enhance the efficacy on selection of improved cultivars for defined traits such as pests and diseases resistance, abiotic stress tolerance, and quality and its post harvest fruit characteristics. Very little knowledge is available this area of research.

The complete genomic knowledge in banana, which covers the complete sequence information, its genes, their expression, recombination and diversity are very important for the improvement of this crop. The genetic maps of

banana will be useful to improve the selection of qualitative traits such as yield and also allow better selection of parents for breeding programmes. The knowledge in banana genomic is very little.

The breeding in most commercially acceptable bananas is very difficult due to its parthenocarpic nature, triploidy and low fertility. Further, the hybridization is complicated by combination of different ploidy levels and by female restitution associated with the formation of unreduced female gametes.

There is an increasing threat for the loss of valuable genetic resources, if effective measures are not taken for conservation and development of database. In absence of database for diversity, there is a likely chance for loosing the claim on resistance source from Indian origin. With growing appreciation of banana and increasing population there will be very high demand for this fruit. If production constraints are not tackled, there can be reduced growth.

High cost of tissue cultured plants, its poor adoptability by the farmers and non-availability of sufficient disease free planting materials (suckers) poses serious problem to the farmers. This situation forces the farmers to plant unhealthy suckers and ultimately spread dreadful viral and bacterial diseases at a quicker phase.

Ever decreasing fertility status of soil as well as crop productivity due to continuous use of excess inorganic manures resulted in increased soil pH, bulk density and decreased soil porosity and organic carbon content. This change in the soil physical properties is evident from the fact of steadily declining bunch weight in all cultivars. Use of pesticides and chemical fertilizers has also deteriorated soil health, besides contaminating air, water and food. There is a need to develop a strategy for organic banana cultivation for export as well as local internal consumption.

The nutrient supplying capacity and pattern in these areas are not coinciding with the nutrient requirement pattern of banana due to soil salinity, sodicity, acidity etc. This is also considered as one of the important bottlenecks in increasing banana production and productivity.

Availability of water for irrigation and soil health due to indiscriminate use of fertilizers and chemicals are going to be the serious threat for banana production in different banana growing states of the country in coming future.

Although considerable efforts have been made towards use of micro - irrigation, fertigation and water conservation for the management of these constrains. But to achieve the production target and quality fruits for domestic and export market, there is a need to invest more capital investment and technology should be designed to have a shift from subsidy driven mode to farmers driven mode.

Insect pests, plant parasitic nematodes and diseases are major constraints in banana production. In addition, losses caused by the biotic stresses are very high which have threatened the banana production in the country though considerable improvement have been achieved, non-adoption of proper technology has alleviated these constraints and improper management of these diseases. Indigenous kits for virus testing are not available for all banana viruses, hence certification standards for TC plants and industries is not available.

The growing trade restriction with the advent of WTO regime, stringent quality control measures like ban on several post harvest fungicides and introduction of HACCP on processed foods pose a threat to growth of the nascent banana export as well as processing industry in India. Non-availability of financial support for the cost intensive processing industries, without collateral, is prohibiting several first generation entrepreneurs from entering the processing of banana.

8.2 New Initiatives

In the present agricultural scenario and WTO regime when the whole world has become a single market, the focus has to be on nutritional security, diversification, value addition and export. To meet the nutritional requirement of the people, for banana, production has to be raised from 16.5 million tonnes to 25.0 million tonnes by 2010 and the industry has to be competitive, quality conscious and diversified in use. Therefore, besides the on- going program, the following areas of research and strategies are the priorities and new initiatives.

i. Broadening of varietal base

To achieve this, the strategy could be introduction, exploitation of natural variability, clonal selection, conventional breeding, and use of somaclonal variants and development of transgenic.

ii. Resource and evaluation based banana production

To make banana industry competitive, quality of natural resources and requirement of plants under given situation will have to be inventorised and the choice of the varieties and strategy for input use will have to be worked out.

iii. Efficient input management

In this case, the strategy should be working out the needs, identification of sources, integrated approach to make inputs cost effective, and environmental friendly.

iv. Quality production

This aspect will have to be tackled through correct choice of the variety, use of disease free planting material (tissue culture) appropriate use of nutrients and water, plant management, bunch management, appropriate maturity indices based on destinations and minimum physical injuries during handling. Standards will have to be evolved.

v. Post harvest handling procedures

This aspect will have to be improved through development of practical maturity indices technique of harvest, handling, transportation, grading, cleaning, and packing keeping in view the status of the farmer and development of facilities keeping a group of farmers in vision.

vi. Product development

Appropriate products will have to be developed depending quality of material available, market demand and export potentials.

vii. Organic farming

Strategy should be identification of organic nutrient sources, enrichment of soils, bio-agents for biological control, botanicals for disease and pest management and integration of different components and development of resistant varieties against major abiotic and biotic stresses.

viii. Precision farming

Inventorization of natural resource base, choice of the variety, development of monitoring indices for various inputs through plant and soil analysis and

threshold level of parasites and use of different input as per standards developed.

ix. Development of efficient tissue culture propagation techniques

Somaclonal variants, expression of viral infection and high cost are limiting the use of tissue culture plants in banana. Diagnostic kits for identification viruses at various stages (Mother plants, during proliferation, primary hardening) will have to be developed and utilized.

x. Identification of factors of resistance

The microorganisms present exclusively in rhizosphere of wilt resistant germplasm should be identified and exploited for bio control. Similarly biochemical mechanism of resistance needs to be investigated.

xi. Botanicals for plant protection

The active ingredients responsible for inhibiting pest nematodes and pathogens in several botanicals should be identified.

xii. Detection techniques for viruses

For identifying infected suckers for freedom from viruses, RT-PCR technique should be developed for BBrMV also.

xiii. Protocol for mass production of bio control agent

For taking bio control to field level, it is necessary to develop protocol for mass multiplication using cheap, easily available substrates.

9. PROGRAMME AND PROJECTS ON TIME SCALE FOR FUND REQUIREMENTS

Sl. No	Research Activities	2005-2010	2011-2015	2016-2020	2021-2025
I	**Crop Improvement**				
1	Exploration, collection, characterization, conservation, evaluation, documentation and utilization of banana germplasm.				
2	Developing biotic and abiotic stress resistant / tolerant banana and plantains through classical breeding				
3	Development of molecular markers s and Marker Assisted Selection for resistance to biotic and abiotic stresses				
4	Isolation of genes responsible for valuable agronomic traits and pest / disease resistance , and sequencing				
5	Development of embryogenic cell suspensions and genetic transformation for improved resistance to biotic and abiotic stresses				
6	Identification and evaluation of mutants and somaclonal variants				
7.	Development of nutritionally enriched banana				
II	**Crop Production**				
1	Nutrient management in different cultivars of banana under different systems of cultivation				
2	Development of technology for modified high-density planting and clump management				
3	Micro irrigation and fertigation studies in major commercial cultivars				

4	Use of growth regulators for manipulation of growth and development including mass multiplication of conventional suckers				
5	Development of technology for organic banana production in major commercial cultivars				
6	Development of micro nutrient schedule for commercial cultivars				
7	Development of leaf nutrient guide for all the commercial cultivars				
8	Development of technology for export of major commercial cultivars				
9.	Evolving of production technologies for disaster management				
III	**Physiology and Biochemistry**				
1	Studies on physiological and bio-chemical basis for drought and salt tolerance mechanism				
2	Characterization of drought and salt tolerance genes through RNAi technology				
3	Physiology of Water Use Efficiency (WUE) and nutrient use efficiency through stable isotope discrimination techniques				
4	Physiological and bio-chemical and molecular basis of biotic stresses				
5	Physiological, bio-chemical and molecular basis of ripening mechanism				

Sl. No	Research Activities	2005-2010	2011-2015	2016-2020	2021-2025
IV	**Post harvest technology**				
1	Development of handling, storage and ripening technology including extension of shelf life using botanicals, bio agents and pre-storage treatment for reducing post harvest losses and promoting export trade.				
2	Development of new value added products (edibles and non-edibles) from various parts of banana like fruits, stem, leaves, peel etc				
3	Development of functional foods for specific targets group like diabetics, sports persons, children and aged people				
4.	Fine tuning, popularisation and commercialisation of all post harvest technologies and value added products and demonstration on pilot scale.				
V	**Crop Protection**				
	Entomology				
1	Screening of Musa germplasm and identification of resistance gene sources for banana weevil				
2	Search for natural enemies of banana weevils and vectors of banana viral diseases and utilization of bio-control agents for managing pest.				
3	Isolation, identification and development of Semio-chemicals (Pheromones / Kairomones) for stem weevil and banana fruit scarring beetle.				

Sl. No	Research Activities	2005-2010	2011-2015	2016-2020	2021-2025
4	Characterization of neuropeptides for the management of stem weevil				
5	Molecular approaches in host plant defence against stem weevil				
	Nematode Management				
1	Distribution Map of major nematodes of banana in India				
2	Studies on host parasitic relationship of nematodes integrated with soil borne pathogens.				
3	Isolation and identification of nematicidal principles in botanicals and their effect on banana nematode				
4	Molecular approaches for the management of major nematode pathogens in banana				
5	Development of Integrated Management Practices for nematodes				
	Pathology				
1	Distribution map of India for important diseases				
2	Molecular characterization of banana pathogens and development of DNA markers for the early diagnosis of banana pathogens				
3	Screening of Musa germplasm for identification of resistant gene sources against major diseases of banana				

Sl. No	Research Activities	2005-2010	2011-2015	2016-2020	2021-2025
4	Identification, isolation and cloning of defense genes from within and outside Musa species for important banana diseases				
5	Use of bioagents/ PGPM and botanicals for the management of banana diseases development of biopesticide formulation and commercialization				
6	Development of effective mass production and delivery system of bioagents for the management of banana diseases				
7	Development of integrated disease management strategies for the control of banana diseases including post harvest diseases				
8	Identification and mass production of effective microbes for quick decomposition of banana wastes				
	Virology				
1	Development of micro arrays/chip based diagnostic technology and or molecular diagnostic kits for simultaneous detection of all banana viruses and their strains occurring in India and neighbouring countries				
2	Development of transgenic plants resistant to multiple viruses through manipulation of coat protein gene, antisense RNA, and replicase and movement protein genes derived from pathogens.				
3	Molecular characterisation of Banana Streak BADNA virus (Para retrovirus) and unravelling of mechanism of integration and excision of endogenous para-retroviral sequence in wild and cultivated bananas				

Sl. No	Research Activities	2005-2010	2011-2015	2016-2020	2021-2025
4	Screening the germplasm for viruses using the kit developed and search for virus resistant gene source				
5	Molecular characterization of banana viruses viz., BBMV, BBTV and CMV.				
6	Study on epidemiology of virus diseases and forecasting for virus disease spread.				
7	Integrated management of virus diseases				

10. LINKAGE, COORDINATION AND EXECUTION ARRANGEMENTS

10.1 Linkages

India being a member in the International Organizations like INIBAP, France, BAPNET, Philippines involved in formulation of research activities on bananas in South East Asian regions. Being a member in the INIBAP sponsored International Musa Testing Program (IMTP), involved in the testing of the global hybrids and also member in the PROMUSA working groups involved in breeding, wilt, weevil and nematodes. Effective linkages with INIBAP have resulted in exchange of germplasm materials and hybrids for testing wilt, Sigatoka leaf spot diseases and nematodes. In addition, linkages also established with other International banana working groups like FHIA, Honduras; IITA, Nigeria; CIRAD, France; QDPI, Australia; TBRI, Taiwan; CNMF, Brazil and CORBANA, Costa Rica. NRCB has linkages with other national institutes like NBPGR, New Delhi; IIHR, Bangalore; BARC, Mumbai; State Agricultural Universities, State Government agencies, commercial tissue culture companies and Private sectors in the areas like germplasm exchange, sharing of materials and know-how, dissemination of information, consultancy and contract research services.

10.2 Coordination and execution arrangements

The coordination with national institutes BARC, DBT, DST, NHB, NHM activities are coordinated by the Director, NRC Banana. The International exchange of germplasm and other materials are coordinated through NBPGR, New Delhi. The coordination with the international agencies like INIBAP, France;

FHIA, Honduras; IITA, Nigeria; CIRAD, France; QDPI, Australia; TBRI, Taiwan; CNMF, Brazil; CORBANA, Costa Rica and BAPNET, Philippines are coordinated by an executive agreements with Indian Council of Agricultural Research, New Delhi.

11. CRITICAL INPUTS

To improve the capabilities of NRCB, additional infrastructure facilities like laboratory buildings, subject-specific training center and Pilot-cum-Demonstration building for processing and value addition, large scale multiplication of bio-control agents, a separate administrative building with an auditorium are required. A critical input like a vehicle for transportation of the staff members, farmers and other visitors is essential to enhance the efficiency of the staff members since the Centre is located 15 kilometers away from the City and is devoid of public transportation facility.

11.1. Funds

Allocation of sufficient funds for execution and success of the identified programs is essential. Liberal funding is needed for purchase of sophisticated hi-tech instruments for carrying out the research program envisaged. Constraints in fund allotment may delay in achieving the goals and the success of the program also delayed. Several research programs involving advanced molecular technologies require state of art equipments and costly chemicals and without these chemicals the success of the research program will be debatable. Requirements of the fund during the 11th Five Year Plan period are enclosed as Annexure.

11.2. Man Power

The Centre is having 15 Scientists in various disciplines to carry out different research program in five major theme areas viz., Crop improvement, Crop production, Crop protection, Physiology and Biochemistry and Post Harvest Technology. The Scientists are supported by technical, administrative and supporting staff members, totaling 47. To disseminate the technologies developed to the end users and farmers, there is a need for a Social Scientist to do extension work and also evaluation and feed back of the technologies developed by the Centre. Even though the Scientists are at present disseminating the knowledge, the role can be better performed by an

Extension / Economic Scientist. In this regard, a recruitment of Social Scientist, particularly Extension is required and is proposed in the 11th FYP proposal.

There is a need for recruitment of a specialized Agricultural Biotechnology Scientist to carry out the research program on molecular breeding under biotechnology work in banana. Since only one Scientist is available in this department, the progress achieved is not appreciable. Hence, an additional hand in this area would help in carrying out the activities ay a faster pace and the work in molecular and biotechnology research activities could be strengthened.

Due to the shortage of Scientist in the improvement program, many activities could not be envisaged to develop hybrids with desirable traits. Recruitment of a Scientist would help in achieving the target proposed in developing newer hybrids with desirable traits.

11.3. Human Resource Development

Human Resource Development is a most vital part for capacity building of the human resource available at the Centre. There is a need to improve the skill and competitiveness to meet the changing trends and demands. Accordingly, short and long term training of Scientists and technical staff in their specific field of specialization within and outside the country is necessary. Training abroad in the cutting-edge technology and also in the mandated research programs would help the research personnel to carry out their programs in a better way. Advanced training are required in molecular breeding techniques, precision farming, drought, semio-chemical, molecular characterization of fungus and viruses and value addition in banana are some of the areas which needs capacity building and training. Participation in international symposia on *Musa* should be encouraged to have a better interaction with international scientists and also exposure to the different systems of growing of banana practiced in different parts of the world.

The technical staff members should be encouraged to equip themselves in better technical skill and also upgrading their knowledge by encouraging them to go for higher studies and research programs. Similarly, the administrative staff should also be given training in computer knowledge and other administrative packages to upgrade their knowledge in administration.

Sufficient financial allocation should be provided to meet out the expenses under human resource development so as to encourage the Scientists and technical personnel to improve their skill and knowledge in the frontier areas.

12. RISK ANALYSIS BASED ON SWOT

The banana production and productivity is hampered by many biotic and abiotic stresses which reduces the productivity by 30-40%. The post harvest losses also account for a 20-30% loss. With the advent of improved research finding to control these biotic stresses and also management of post harvest losses, it is expected to bring the desired results. Research emphasis in solving the major diseases like Sigatoka leaf spot and nematode through molecular approaches like transgenic and polyploidy breeding has resulted in encouraging results. Due to the complexity of the breeding in banana, there has been little outcome in the past. Even though some success has been obtained in FHIA and IITA programs, extensive research programs on molecular breeding with the use of molecular markers, transgenic and MAS would help in breaking the barriers and production of hybrids with desired traits is possible. Identification of resistant gene sources for the major biotic stresses would help in breeding program. Efficient bio-control agents identification, would lead to better integrated pest management strategies without affecting the environment with minimum cost. Development of molecular diagnostic kit for identification and elimination of viruses from the mother plants and tissue culture plants is a boon to the farmers. Development of technology on reduction on post harvest losses and processing could reduce the post harvest losses for better remuneration to the farmers. In addition, commercialization of value addition technology has lead to rural employment generation and also value added products development to get a better market price during the glut season.

There is a greater opportunity for export of traditional bananas like Rasthali, Ney Poovan, Red banana, Nendran, Virubakshi etc due to the ethnic Indian population in many countries. Due to the greater awareness for banana in nutrition and its medicinal value, there is a great demand for the traditional varieties than the Cavendish bananas and also there is lot of scope for export of organic bananas to the European and Japanese markets.

13. PROJECT REVIEW, REPORTING AND EVALUATION ARRANGEMENTS

Project review shall be done annually by the Research Advisory Committee (RAC) followed by Institute Research Council (IRC). The research programs are reviewed externally for its subject contents and feasibility studies and it was scrutinized for approval by the Institute Research Council. The approved research activities and technical programs were reviewed by the Research Advisory Committee for further improvement and modifications. The Centre's progress was evaluated once in five years by Quinquennial Review Team (QRT) appointed by the ICAR, New Delhi.

14. RESOURCE GENERATION

NRC Banana generates additional resources by selling of the technologies developed, offering training programs on various aspects of banana production, protection and value addition. In addition, consultancy service to the clients and contract services to test the tissue culture plants and mother plants against virus diseases and also product testing of the private companies are the additional sources. It also generates funds as institutional charges for the services provided to the external funded projects. In addition, the Centre is having 38 hectares farm where bananas and paddy in rotation is grown which is also a source of revenue generation.

Revenue Generation (Rs. lakhs)

Sl.No	Year	Targets	Achieved
1	2002-2003	3.50	2.77
2	2003-2004	5.00	5.98
3	2004-2005	10.00	12.19
4	2005-2006	15.00	6.65
5	2006-2007 Up to September,2006	10.00	1.38
	Total	43.50	28.97

15. OUT COME OF INSTITUTION WITH TRADE, INDUSTRIES AND FARMERS

15.1 Trade

The Centre has developed various production technologies coupled with pre and post harvest technologies for obtaining the exportable quality banana fruits. In addition, the Centre has developed a protocol for the handling, transportation, packaging and storage of banana fruits for export trade. The Centre has developed the technology for extending the shelf life of green bananas and also ripening techniques.

15.2 Industries

The National Research Centre for Banana has developed various commercially viable value added products on banana. These technologies have been sold to the entrepreneurs on a non-exclusive basis to start viable industries on banana products. Banana farmers and Self help groups were encouraged to become entrepreneurs by offering training on value added products. Many farmers from Gujarat, Maharashtra, Kerala and Tamil Nadu have under gone the training programs and have started their own industries on value added products like banana chips, fig, thokku, pickle, banana juice and powder. The use of molecular diagnostic kit developed by the Centre has helped the commercial tissue culture companies in the production of virus free tissue culture planting material, for the large scale use of disease free planting material by the farmers.

15.3 Farmers

The Centre has released a variety 'Udhayam' for the benefit of the banana farmers which gave 40-50% higher yield than the local Karpuravalli. Improved production technologies on high density planting, drip, fertigation schedule, package of practices for tissue culture plants, use of alternate sources for in-organic fertilizer and micro nutrient requirement have been disseminated for adoption by the banana farmers. Many farmers have adopted high density planting and drip/fertigation with tissue cultured plants were benefited. The Centre has developed integrated pest and nematode management using pseudostem trap for the control of weevil, use of bio-control agents for the control of weevil and nematodes and trap-crop for the control of nematodes.

These technologies have been demonstrated in the farmers' field and are being adopted by the farmers successfully. Use of molecular diagnostic kit has helped the farmers to obtain virus free planting material for better productivity and maximum profit. Use of bio-control agents for the control of wilt and fungicides schedule for the control of leaf spot diseases and heart-rot has been standardized and are being adopted by the farmers effectively in banana.

In addition, the Centre is organizing Kissan Mela, Campaign and Front line demonstration in the farmer's field for demonstrating the technologies developed by the Centre for the benefit of the farming community. In addition, through the electronic media like news paper, All India Radio, Doordarshan, information are provided to the farmers for the management of sudden outbreak of pest and diseases.

16. EXPORT POTENTIAL AND MARKETABILITY OF RESEARCH OUTPUT AND ITS IMPACT IN WTO REGIME

Even though India is the largest producer of banana, the export of banana is to the tune of 0.01 % due to the poor quality of the fruits and high cost of production. India being a tropical country, there is a great potential for year-round production and availability of different varieties for export. But in many states, banana is not cultivated on commercial basis with intensive cultivation and mostly grown in home-stead garden under natural condition. This situation has given an opportunity for export of banana as organically grown due to the non-application of fertilizer and non-use of insecticides and fungicides particularly in north eastern region and hilly areas of Tamil Nadu and Kerala. There are choice varieties like Red banana, Virupakshi (Pome), Nendran, Rasthali (Silk), Manoranjitham are suitable for export due to its attractive fruit colour, taste, flavour and quality.

After the opening up of the trade and WTO regime, the banana trade and export is open to India also. There is a great potential for export of banana and plantain to Europe and US markets. By forming cooperatives, banana can be produced scientifically adopting improved production technologies to suit the specifications prescribed for export in a large scale. Production technologies have to be developed exclusively for export trade so as to meet the specifications prescribed by the exporting countries.

17. UTILITY OF RESEARCH OUTCOME TO FARMERS AND END USERS

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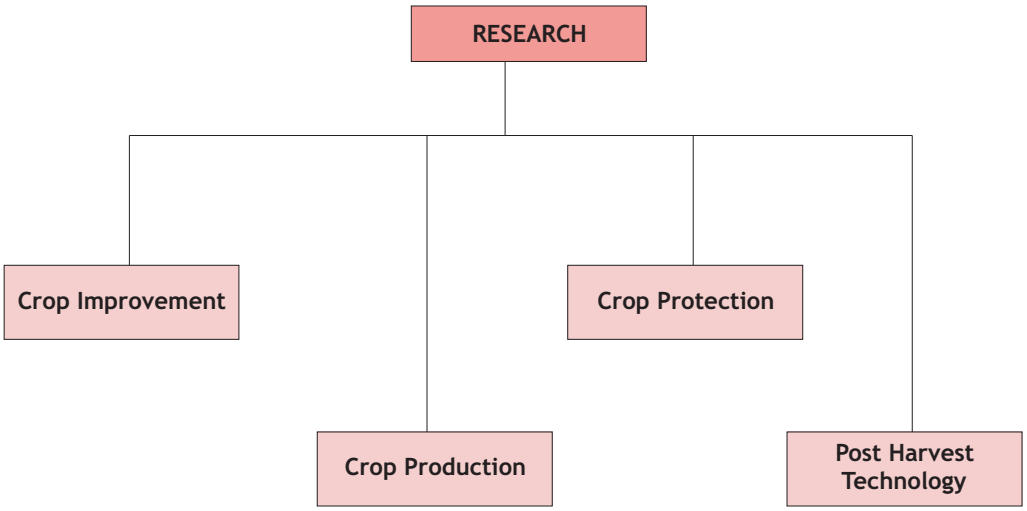
18. ANTICIPATED CONSTRAINTS

Due to the indiscriminate use of diseased planting material, the yield level is slowly declining and also the soil is getting infected with the soil pathogens like wilt and nematodes. There is a possibility of evolving new races of pathogens which may infect the available resistant varieties in the near future. Since the opening up of the trade and large scale proliferation of tissue culture companies and discriminate import of plant material from other countries without proper quarantine measures may lead to introduction of new pest, diseases and viruses in India like Race-4 of Fusarium, Moko Bacterial wilt etc. Introduction of pests in the non-traditional areas may

cause an outbreak of pests/diseases so that the entire crop may be wiped out.

19. SCIENTIFIC DIVISIONS

The Centre is having four major scientific divisions viz. Crop Improvement, Crop Production, Crop Protection and Post Harvest Technology.



BUDGET REQUIREMENT FOR XIth PLAN

(Rs. In lakhs)

Head	XI Plan Period Outlay					
A. Recurring	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total**
1. Pay & Allowances	0	3.00	5.00	6.00	7.00	21.00
2. Traveling Allowances	2.00	2.50	2.50	3.00	3.00	13.00
3. Contingencies	80.00	85.00	90.00	100.00	100.00	455.00
4. HRD	2.00	2.00	2.50	2.50	3.00	12.00
Total (A)	84.00	92.50	100.00	111.50	113.00	501.00
B. Non-Recurring						
1. Equipments	50.00	50.00	100.00	100.00	66.00	366.00
2. Works	50.00	50.00	150.00	100.00	50.00	400.00
3. Library	3.00	3.00	3.00	3.00	3.00	15.00
4. Furniture & Fixtures	3.00	3.00	2.00	2.00	2.00	12.00
5. Vehicles	0	0	7.00	0	0	7.00
6. Livestock	0	0	0	0	0	0
7. Land	0	0	0	0	0	0
8. Others	0	0	0	0	0	0
Total (B)	106.00	106.00	262.00	205.00	121.00	800.00
Grand Total (A+B)	**190.00**	**198.50**	**362.00**	**316.50**	**234.00**	**1301.00**